

## THE REINFORCEMENT OF SHORT INTERRESPONSE TIMES<sup>1</sup>

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Five contingencies were superimposed successively on a variable-interval schedule of reinforcement. In each of the resulting conditions, a different short, interresponse time was reinforced and an interresponse-time distribution was obtained from each of three pigeons. The lower bound of the reinforced interresponse times ranged from 0.3 to 2.4 sec. The resulting distributions were combined, according to a rationale based upon concurrent operants, induction, and a property of variable-interval schedules, to describe the interresponse-time distributions from a variable-interval schedule.

Many accounts of free-operant behavior depend on the presumed effects of the differential reinforcement of interresponse times (IRTs). To give just one example, variable-ratio schedules of reinforcement are said to generate higher response rates than variable-interval schedules with the same average reinforcement rates because the ratio schedules provide relatively higher reinforcement rates for short IRTs (Ferster and Skinner, 1957, pp. 399-405). Such accounts presuppose a substantial degree of behavioral control by the differential reinforcement of IRTs lying within the range typically produced by variable-interval and variable-ratio schedules. In spite of the acknowledged importance of this presupposition, few data exist on the differential reinforcement of these IRTs. Most of the work on IRTs has involved schedules that differentially reinforce low response rates; but the reinforcement of the long IRTs (*e.g.* 10, 20, or 30 sec and longer) in these schedules may tell little about the reinforcement of short ones (*e.g.*, 1, 2 sec and shorter). At least two lines of evidence suggest that in fact short IRTs may behave quite differently from long

ones. First, Blough (1963, 1966) has found that short IRTs are less well controlled by various experimental contingencies than long ones. Second, Millenson (1966) and Malott and Cumming (1966) account for some of their results by either a greater susceptibility by short IRTs to reinforcement, or by a response bias in favor of short IRTs. The present paper describes some of the effects of the differential reinforcement of short IRTs and discusses the relevance of these effects both to the various hypotheses about short IRTs and to an analysis of schedules in terms of concurrent operants. This analysis usually is complicated by the dependence of the relative frequencies of reinforcement on the behavior of the subject. These relative frequencies were controlled in the present experiment by "pacing" contingencies (Ferster and Skinner, 1956, p. 498). In each of the resulting schedules, reinforcement followed only those responses that terminated IRTs lying within a narrow interval.

### METHOD

#### *Subjects*

Three male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. They had been exposed previously to arithmetic variable-interval schedules.

#### *Apparatus*

Interresponse times were classified by a Foringer multiple class time analyzer stepped by an electronic timer. A Lehigh Valley Elec-

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tronics pigeon key was operated by a minimal force of approximately 22 g.

Procedure

The birds were first placed on an arithmetic variable-interval schedule with a mean time of 1 min between reinforcements. After 10 days on this schedule, one bird developed post-reinforcement pauses and all three birds emitted occasional bursts of responses. To establish a more nearly constant response rate and a more uniform response topography, reinforcements were programmed on a 1-min variable-interval schedule in which the reinforcements per opportunity were approximately constant (Catania and Reynolds, 1963). The probability of an assignment of a reinforcement was approximately 0.1 every 8 sec, except at long times after reinforcement. Also, after every response, the key light was turned off for 0.04 sec; a subject was thus provided with visual feedback. Soon after these two contingencies were introduced, the cumulative records showed a more nearly constant response rate and the frequency of bursts of responses greatly declined. The present reinforcement schedule was chosen partly for three interrelated reasons: 1-min variable-interval schedules are in widespread use; constant response rates are probably easier to analyze; and the time since reinforcement is not a major controlling variable.

After behavior became stable on the variable-interval schedule, different pacing contingencies were superimposed. They are shown in Table 1. In this paper, "paced variable-

interval ( $T_1$ ,  $T_j$ )" means that a response was reinforced if the variable-interval tape programmer had assigned a reinforcement and if the response ended an IRT longer than  $T_1$  sec but shorter than  $T_j$  sec. When a reinforcement had been assigned, the tape stopped and reinforcement continued to be available until a response ended an IRT in the interval ( $T_1$ ,  $T_j$ ) sec.

The paced variable-interval (0.3, 0.6) and variable-interval (1.2, 1.8) conditions were replicated to observe the effects of different reinforcement histories. The purpose of the two schedules with differential reinforcement of low rates was to reduce the response rate to a level far below the optimal level for the replication which would follow.

The data before the eighth reinforcement were not recorded for the variable-interval and the paced variable-interval (0.3, 0.6) conditions in order to exclude warm-up effects. For the same reason, the data preceding the sixth reinforcement were discarded in the other conditions. Each session lasted about 47 min. Reinforcement was access to mixed grain for 3 sec.

In the variable-interval condition, the first response in a session was always reinforced. But in the paced conditions the first response was never reinforced; however, by the time a bird was placed in the box the tape programmer had always assigned a reinforcement, and the first response that ended an appropriate IRT was reinforced. Also, the response terminating a latency after a reinforcement was sometimes reinforced in the variable-interval condition, but never in the paced conditions.

The method of partitioning the IRT continuum into discrete classes was a compromise because the apparatus limited the number of classes to 11, and, as will be seen below, one purpose of the experiment required that the same partitioning be used for all conditions. As the length of the reinforced class increased, its width was increased in order to make the paced distributions more nearly comparable (*cf.*, Malott and Cumming, 1964). The results show that the selected class-width of 0.3 sec was a satisfactory compromise.

RESULTS

The IRT distributions from the last four days of each condition are shown in Fig. 1.

Table 1  
Experimental Conditions

Schedule	No. of Days
Arithmetic variable-interval 1 min	10
Constant reinforcements per opportunity	11
variable-interval 1 min	
Paced variable-interval (0.3, 0.6) sec	11
Paced variable-interval (0.6, 0.9) sec	12
Paced variable-interval (0.9, 1.2) sec	16
Paced variable-interval (1.2, 1.8) sec	12
Paced variable-interval (1.8, 2.4) sec	18
Paced variable-interval (0.3, 0.6) sec	16
Constant reinforcements per opportunity	30
variable-interval 1 min	
Differential reinforcement of low rate 2.8 sec	10
Differential reinforcement of low rate 7.7 sec	6
Paced variable-interval (1.2, 1.8) sec	21

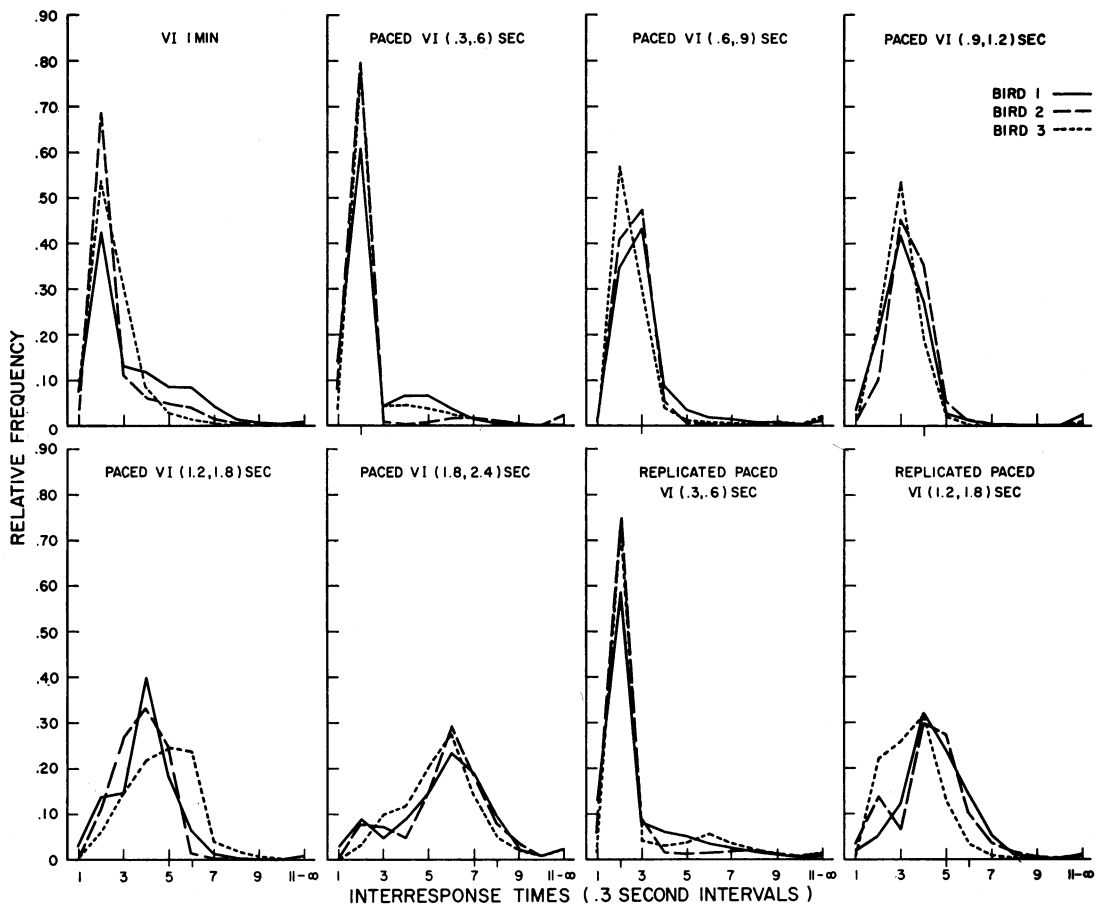


Fig. 1. Interresponse-time distributions from each of three birds. In each paced schedule, reinforcements were programmed only for responses terminating interresponse times between the two indicated values. This reinforced interval is indicated by a short vertical line that extends below the x-axis.

The conditional IRT distributions, *i.e.*, the IRTs/OP, are shown in Fig. 2. (See Anger, 1956, 1963, and McGill, 1963, for valuable discussions of this transformation of the IRT distribution.) The reinforced intervals in the paced conditions are marked in the figures with vertical lines that extend below the x-axes. Table 2 gives the numbers of responses upon which the figures are based. Responses which terminated latencies after reinforcements are excluded from the distributions because they presumably were under the control of different variables.

The IRT distributions from the variable-interval condition have their modes in the interval (0.3, 0.6) sec. For Birds 1 and 2, the conditional distribution was bimodal: the first mode was in the interval (0.3, 0.6) sec and the second was near 2 sec. For Bird 3, the conditional distribution peaked in the interval

Table 2

Absolute frequencies of responses over the last four days of each condition.

	Bird 1	Bird 2	Bird 3
Variable interval	9140	12,770	11,678
Paced variable interval (0.3, 0.6)	14,214	14,735	15,230
Paced variable interval (0.6, 0.9)	11,241	11,914	12,276
Paced variable interval (0.9, 1.2)	8670	10,174	10,975
Paced variable interval (1.2, 1.8)	7680	7184	9384
Paced variable interval (1.8, 2.4)	3462	5273	5439
Replication of Paced variable interval (0.3, 0.6)	13,715	14,869	12,594
Replication of Paced variable interval (1.2, 1.8)	6675	7798	8510

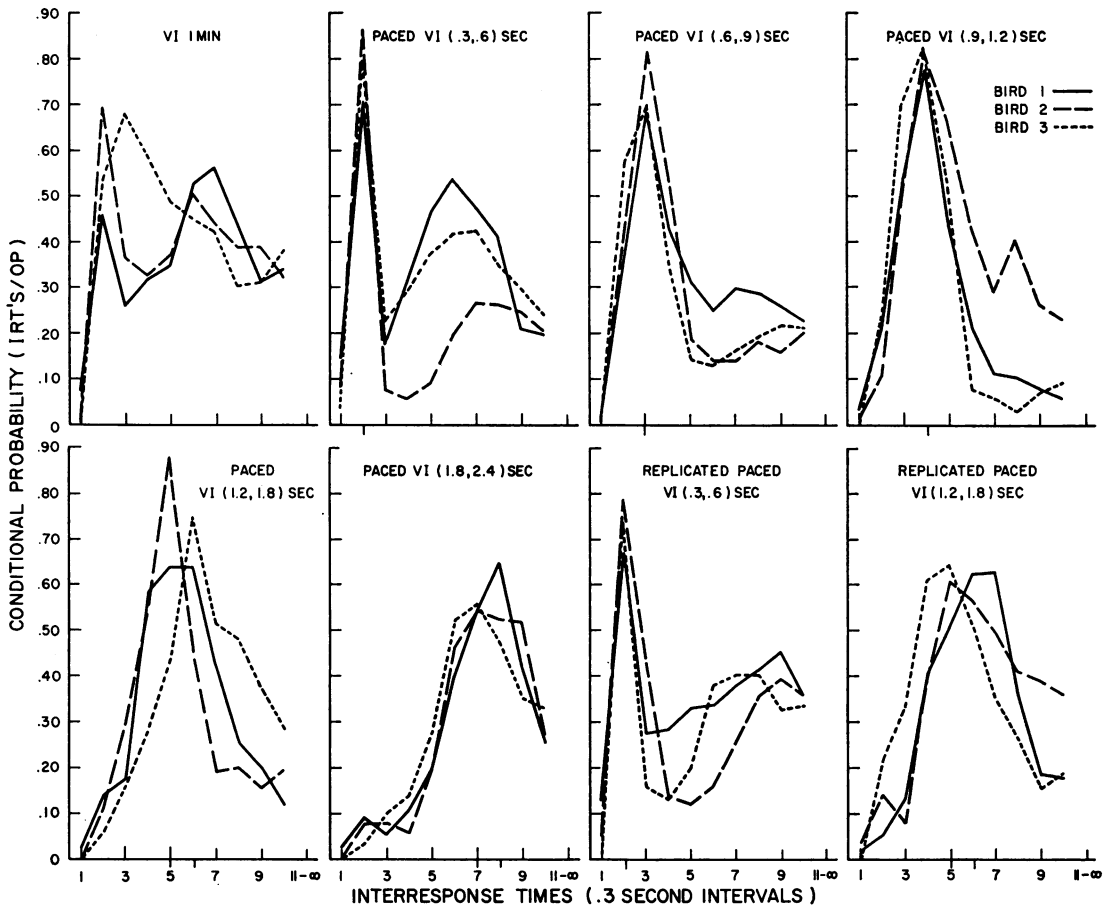


Fig. 2. Conditional IRT distributions from each of three birds. See legend for Fig. 1.

(0.6, 0.9) sec and did not have a second mode similar to those for Birds 1 and 2.

The IRT distributions from the paced variable-interval conditions had modes in the reinforced intervals for all three birds when the reinforced interval was (0.3, 0.6) sec, for two birds when the reinforced interval was (0.6, 0.9) sec, and for one bird when the reinforced interval was (1.2, 1.8) sec. When the paced variable-interval (0.3, 0.6) condition was replicated, the mode was actually in the first half of the reinforced interval. Between 55% and 70% of all the responses in this condition were made between 0.30 and 0.45 sec after the preceding response. When the mode of an IRT distribution was not in the reinforced interval, it was invariably in the interval just before the one reinforced. The heights of the modes decreased as the reinforced interval became longer. On the other hand, the modes of the conditional distributions were

in the reinforced interval in all but one case and remained almost constant as the reinforced interval was lengthened. The replication of the paced variable-interval (0.3, 0.6) schedule produced behavior very similar to that obtained originally. Even the secondary modes in the conditional distributions were similar, in spite of the relatively small number of long IRTs in this condition.

The replication of the variable-interval (1.2, 1.8) condition produced distributions somewhat less similar to the original distributions. However, as in the original condition, the modal IRT was displaced to the interval immediately preceding the reinforced interval. Therefore it does not seem likely that the displacement in the other distributions resulted from the order in which the conditions were presented. The attempt to replicate the original variable-interval performance was least successful. Even though the replication

was continued for 30 days, response rate continued to fluctuate widely, both over days and over different interreinforcement intervals.

Figure 3 includes some representative cumulative records whose two most important features are that the response rate appears to have been nearly constant if the warm-up effects are discounted, and the average rate decreased as the reinforced IRT was lengthened. The cumulative records for Bird 1 were

the least stable from day to day and departed furthest from strict linearity. For the paced variable-interval (1.8, 2.4) condition, the response rate for Bird 1 gradually decreased throughout the session. Furthermore, in several of the paced schedules the average rate determined for Bird 1 was made up of two distinct components, a rate that within any small time segment was roughly constant, and a zero rate.

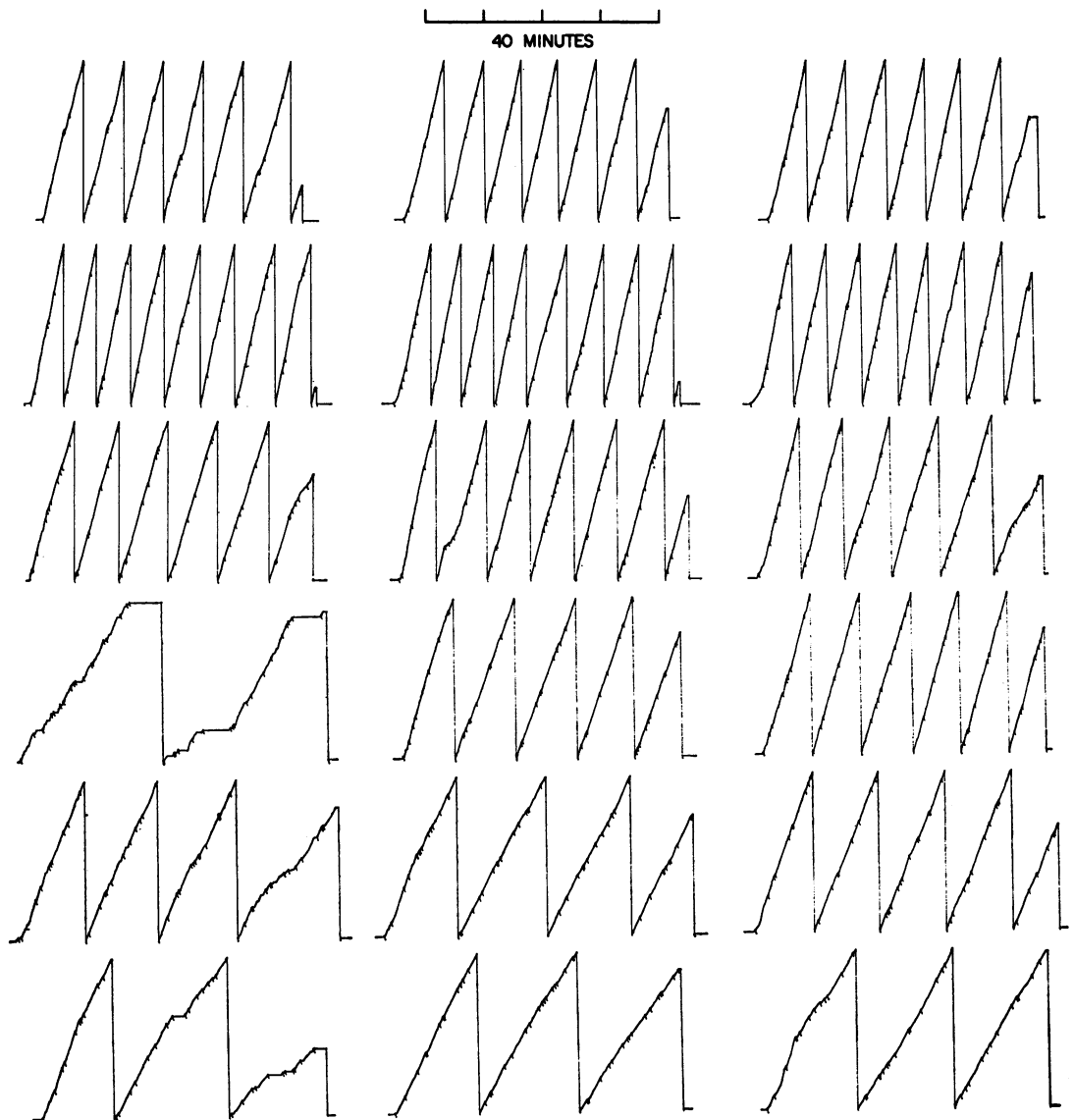


Fig. 3. In each row are three cumulative records from a day representative of the last four days in a condition. The conditions are, from top to bottom: original variable-interval, paced variable-interval (0.3, 0.6), (0.6, 0.9), (0.9, 1.2), (1.2, 1.8), and (1.8, 2.4) sec. The records for Birds 1, 2, and 3 are shown respectively in the left, middle, and right columns. The recorder pen reset after a vertical excursion of 500 responses.

## DISCUSSION

The analysis of schedules in terms of the differential reinforcement of IRTs would become more difficult if the reinforcement of an IRT had different effects after different reinforcement histories. But the replications of the paced variable-interval (0.3, 0.6) and (1.2, 1.8) conditions indicate that the reinforcement history of a bird may not change some of the important properties of the data, such as the modal IRT or even the general shape of the IRT distribution. Malott and Cumming (1964) found that replications were less successful as the relative width of the reinforced IRT decreased. The present data agree with this finding because the replication of the variable-interval (0.3, 0.6) condition was somewhat more successful than the replication of the variable-interval (1.2, 1.8) condition, and  $(0.6-0.3)/0.3 > (1.8-1.2)/1.2$ . Anger (1956) did not succeed in recovering the original behavior in a variable-interval schedule after his rats received training in which IRTs were selectively reinforced. The present experiment essentially replicated Anger's finding, and his account in terms of "semi-stable" states may apply here. Or perhaps the original variable-interval behavior was not recovered because the intervening paced schedules generated behavioral chains consisting of, *e.g.*, sequences of regularly spaced, yet abortive pecks (Blough, 1963; Nevin and Berryman, 1963; Laties, Weiss, Clark, and Reynolds, 1965). Such chains were observed in the present study. Adventitious reinforcement may have maintained them in the replicated variable-interval schedule, and could also account for the instability observed in that condition.

The modal IRT in the present experiment was not in the reinforced interval but was, in many instances, in the interval preceding the ones reinforced. This displacement conflicts with a theory developed by Norman (1966). But in studies of the differential reinforcement of low rates of responding, the modal IRT often has been observed to appear in an interval shorter than the ones reinforced (Conrad, Sidman, and Herrnstein, 1958; Farmer and Schoenfeld, 1964; Kelleher, Fry, and Cook, 1959; Sidman, 1956; Staddon, 1965). Malott and Cumming (1964), in one of their studies of the selective reinforcement of IRTs, showed that the modal IRT tends to shift toward the

left when the relative width of the reinforced interval decreases. It is possible that the displacement results from a bird's inability to discriminate times since the last response and from the fact that short IRTs reduce the number of opportunities for longer ones. In other words, if a conditional distribution measures primarily a bird's ability to discriminate time intervals, then the IRT distribution merely reflects this discriminability, because, of course, the latter distribution is determined by the former (McGill, 1963). However, the conditional distributions are almost surely determined by several variables. In particular, a bird may sometimes not suppress an incorrect, short IRT, even when the bird can discriminate the short interval from the reinforced ones (Blough, 1966; Reynolds, 1964, 1966). No matter what the reason, the displacement does appear often and quantitative analyses of behavior will have to deal with this possibly non-intuitive fact.

Hypotheses about response bias (Malott and Cumming, 1966) and about differential susceptibility to reinforcement (Millenson, 1966) have been advanced to account for the development of high frequencies of short IRTs when these responses actually lower the rate of reinforcement or at least have lower reinforcement probabilities. Both hypotheses may be variously interpreted. One might expect that if a response bias operated in favor of short IRTs then each of the present paced distributions would tend to be shifted to the left of its respective reinforced class of IRTs. As discussed in the preceding paragraph, this shift did appear in the distributions of relative frequencies. But the magnitude of the shift seems too small to account for the high relative frequencies of short IRTs observed by Malott and Cumming and discussed by Millenson. Furthermore, if it is true that this shift mostly reflects the greater number of opportunities for shorter IRTs, then to speak of it as a product of response bias would be misleading.

If short IRTs are "more susceptible to reinforcement" than are long ones, then one might expect to find either of two phenomena. Specifically, this differential susceptibility might reveal itself in differences between steady-state behavior produced by the exclusive reinforcement of short or of long IRTs. Or it might reveal itself in differences between the

rates at which these steady-state levels of performance are achieved. The first interpretation might imply that in the present experiment each paced distribution would be more heavily weighed on the IRTs shorter than the reinforced ones. Thus, this interpretation leads to expectations similar to those of the response bias idea. Again, little support for this idea can be found in the present data. What support does exist may only reflect different numbers of opportunities for the different IRTs. Alternatively, the first interpretation might imply that in the present experiment the paced distributions would become progressively more sharply peaked at the reinforced IRT as it became shorter. Thus, the relative frequency distributions do offer some support for this interpretation, but this support virtually disappears when the conditional distributions are examined. Obviously, the data required to test the second interpretation are not provided by the present experiment. In short, the data do not dispute that short IRTs may be more susceptible to reinforcement than long ones, or that response bias operates in their favor, but the data do appear to restrict the possible interpretations of these ideas.

In summary, the present data clearly show that selective reinforcement can bring short IRTs under good experimental control. Furthermore, the degree of control over short IRTs seems to be at least as good as it is over long ones. This effective control indirectly supports the view that the differential reinforcement of IRTs is an important controlling variable in schedules that produce short IRTs.

Such good control is assumed when various schedules are analyzed as concurrent schedules of reinforcement for different IRTs. The control in the present experiment was good, but not perfect. When the different responses in a concurrent schedule are different IRTs, the reinforcement of one response presumably will increase not only the probability of that specific response but will increase, for example, by induction (Skinner, 1938), the probabilities of adjacent responses as well. Indeed, each of the paced distributions of the present experiment measures the induction around a different class of reinforced IRTs. If the reinforcement of different IRTs, along with the induction, largely determines performance on variable-interval schedules, then the perform-

ance would presumably be a combination of the present paced distributions. This analysis is made more specific by incorporating a suggestion, made by Anger (1956) and Morse (1966), that the relative frequencies of reinforcement of the IRTs control variable-interval performance. According to this idea, the combination discussed here might be expected to equal a weighted sum of the paced distributions, with the weight for each paced distribution equal to the relative frequency of reinforcement, in the variable-interval performance, of the reinforced IRT of that paced condition.

A specific form of this method of combining paced distributions to predict variable-interval performance is suggested by a certain property of variable-interval schedules: the relative frequency of reinforcement of a class of IRTs must approximately equal the proportion of the duration of the session consumed by all IRTs in that class. That is, except for sampling fluctuations, it would usually be expected that

$$\frac{R_i}{\sum_{j=1}^N R_j} = \frac{F_i \cdot T_i}{\sum_{j=1}^N F_j \cdot T_j} \quad (1)$$

where  $R_k$  is the frequency of reinforcement,  $F_k$  is the frequency, and  $T_k$  is the length, of the  $k^{\text{th}}$  class of the  $N$  classes of IRTs. The denominator on the right is the total session duration. If we let

$$\frac{R_i}{\sum_{j=1}^N R_j} = \pi_i$$

and rearrange terms, (1) may be written as

$$F_i = \pi_i \frac{\sum_{j=1}^N F_j \cdot T_j}{T_i} \quad (2)$$

which gives the frequency of IRTs in the  $i^{\text{th}}$  class as a function of the relative frequency of reinforcement of the  $i^{\text{th}}$  class, the length of the  $i^{\text{th}}$  class, and the session duration.

The relationship expressed by (2) suggests, as explained below, that we let the combining rule be

$$F_i = \sum_{j=1}^N \pi_j F_{ij} \quad (3)$$

where  $F_i$  is the predicted frequency of IRTs in the  $i^{\text{th}}$  class of the variable-interval con-

dition, and  $F_{ij}$  is the absolute frequency of IRTs in the  $i^{\text{th}}$  class from the paced schedule in which IRTs in the  $j^{\text{th}}$  class were reinforced. The reason why (2) suggests this particular definition of  $F_{ij}$  in (3) is to be found in the limiting case for which there is no induction. In that case each response in a paced schedule ends an IRT in the reinforced class and (3) reduces to  $F_i = \pi_i F_{ii}$ . Therefore, from (2) it is obvious that we must let

$$F_{ii} = \frac{\sum_{j=1}^N F_{ij} \cdot T_j}{T_i}.$$

That is, we must let  $F_{ii}$  be the absolute rather than, say, the relative frequencies. In the present case it is clearly necessary for (3) to be consistent with the limiting case because, if the  $F_{ij}$  are relative frequencies, then  $F_i$  is severely underpredicted for the shorter IRTs. In part, the successful use of (2) to define  $F_{ij}$  merely reflects the good control achieved by the paced schedules. In other words, each paced distribution is heavily weighted near its reinforced interval.

A summated distribution was computed according to (3) for each bird. Five IRT classes were used: (0, 0.6), (0.6, 0.9), (0.9, 1.2), (1.2, 1.8), and (1.8, 2.4) sec. These classes were chosen so that each of them would have a non-negligible frequency of reinforcement associated with it in the original variable-interval performance. The interval (0, 0.6) is functionally the same as (0.3, 0.6) since so few responses terminated IRTs shorter than 0.3 sec. That is, the actual and the predicted frequencies in (0, 0.3) both were approximately zero. The IRTs greater than 2.4 sec had to be excluded because there were no paced conditions with a reinforced interval greater than 2.4 sec. The relative frequencies of reinforcement, that is the  $\pi_i$ , are shown in Fig. 4. Notice that the  $\pi_i$  are also the relative time rates of reinforcement, since the unit of time cancels out of the appropriate expression and reduces to the left-hand side of (1). The three distributions from each paced condition were multiplied by a constant ranging only from 0.91 to 0.99 to compensate for slightly different session durations (actually from the sixth or eighth reinforcement) in the different conditions and across birds within a condition. The IRT distributions and the conditional IRT distributions were computed in the ordinary way (Anger, 1956) from the ab-

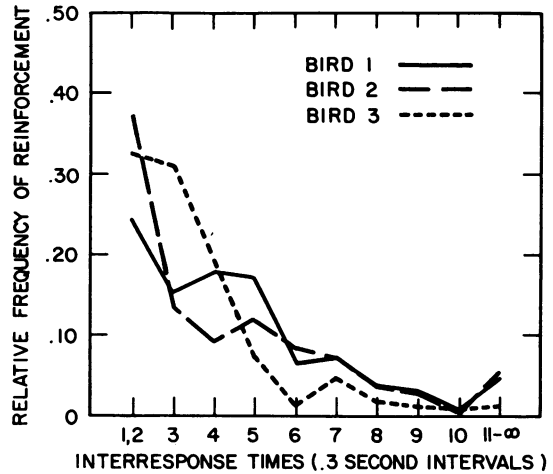


Fig. 4. Relative frequencies of reinforcement, *i.e.*, number of reinforcements for a given IRT divided by the total number of reinforcements, over the last four days of the original variable-interval schedule.

solute frequencies, *i.e.*, from the  $F_i$ . An average distribution was obtained by taking the arithmetic means of the individual distributions.

The top panels in Fig. 5 show both the summated IRT distributions and the corresponding IRT distributions produced by the variable-interval schedule. The individual distributions on the left side of the figure show that the summated distributions roughly approximate the original distributions. The fit between the two curves is quite close for Bird 2, but less so for Bird 1. In the latter case, the summated distribution does not duplicate the secondary mode in the interval (1.8, 2.4) sec. But the behavior of Bird 1 was as a rule less orderly and stable than that of the other two birds, as illustrated by the cumulative records in Fig. 4. With few exceptions, the general features of the summated distributions resemble those of the real IRT distributions. Several of the differences between predicted and obtained points are without doubt statistically significant; nevertheless, the matching seems to be adequate for present purposes. The close match between the average distributions, which is shown on the right side of Fig. 5, supports the method of summated distributions. However, not every individual curve resembles the average curve.

The conditional IRT distributions are shown in the bottom panel of Fig. 5. Again, the approximation between predicted and observed distributions is close for Bird 2 but less so for Birds 1 and 3. In particular, the sum-



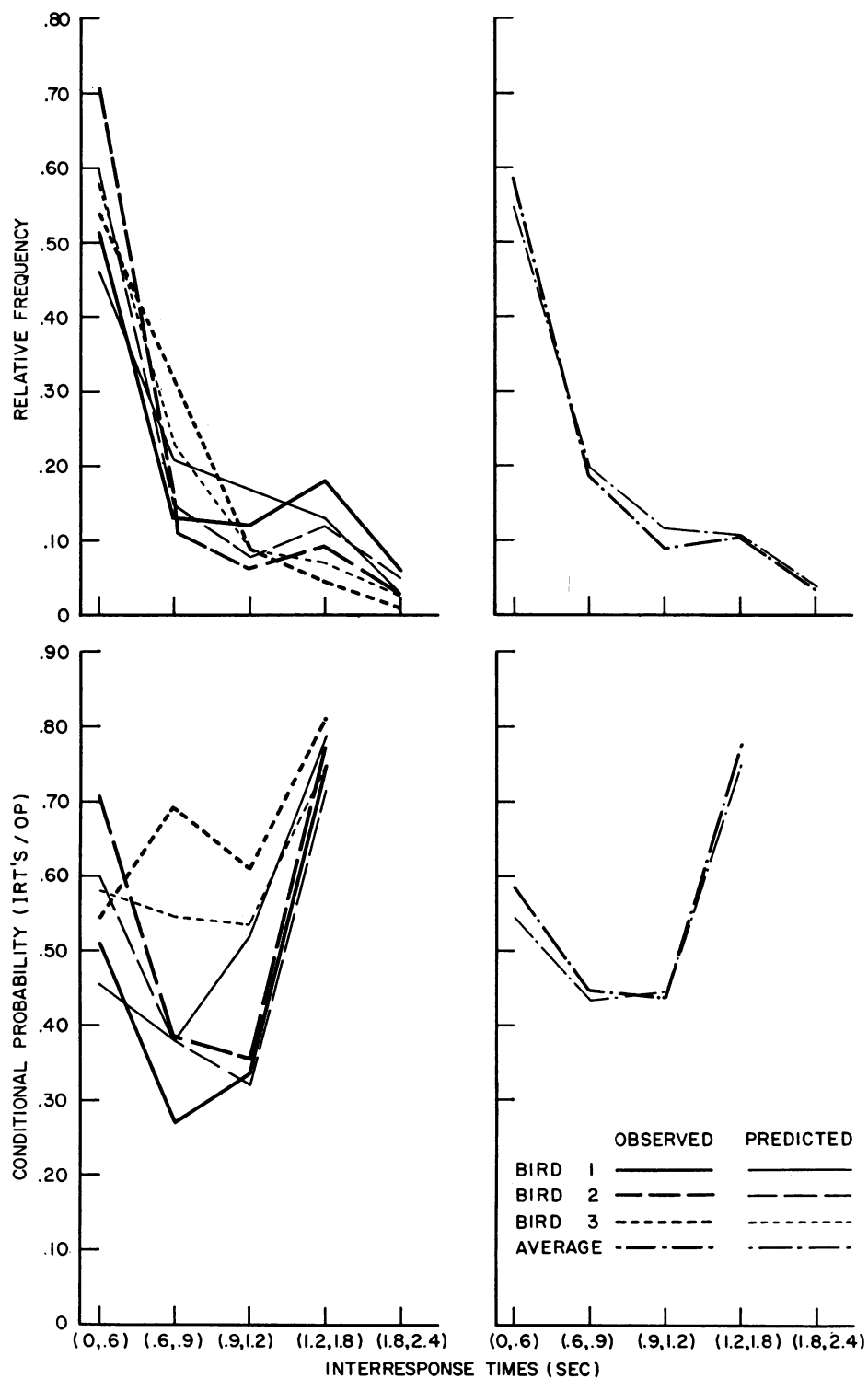


Fig. 5. Predicted and obtained distributions. Each predicted distribution is a simple combination of the distributions obtained from the paced variable-interval conditions. The predicted curves roughly match the obtained curves.

mated distributions for Bird 3 fail to predict the mode in the interval (0.6, 0.9) sec. As in the case of the average IRT distributions, the match between the average conditional IRT distributions is good.

Figure 5 demonstrates that a rationale based on the differential reinforcement of IRTs, induction, and a property of variable-interval schedules, can provide a rough description of variable-interval behavior. A particularly desirable goal for further work would be the development of a more general rationale that would reduce, for variable-interval schedules, to the present one. This rationale will somehow have to allow for different relationships between relative frequencies of responses and of reinforcements. Thus, the counterpart of (2) is different for other schedules, such as variable-ratio schedules, and does not exist for still others, such as Anger's synthetic variable-interval schedule (Anger, 1954). Indicative of the primitive state of work in this area is the absence of alternative rationales for combining the paced distributions. Such alternatives would ease the task of judging the adequacy of the present formulation. In addition, much more needs to be known about the effects of different deprivation levels and reinforcement densities on the paced distributions. These variables undoubtedly affect the paced distributions and therefore need to be included in the rationale. Some work has been done (Revusky, 1963) but so far the results have been too inconclusive to suggest any specific modifications or generalizations of the present formulation.

## REFERENCES

- Anger, D. The effect upon simple animal behavior of different frequencies of reinforcement. 1954. Document No. 7779, ADI Auxiliary Publications Project, Photoduplication Service, Library of Congress.
- Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. *J. exp. Psychol.*, 1956, **44**, 145-161.
- Anger, D. The role of temporal discriminations in the reinforcement of Sidman avoidance behavior. *J. exp. Anal. Behav.*, 1963, **6**, 477-506.
- Blough, D. S. Interresponse time as a function of continuous variables: A new method and some data. *J. exp. Anal. Behav.*, 1963, **6**, 237-246.
- Blough, D. S. The reinforcement of least-frequent interresponse times. *J. exp. Anal. Behav.*, 1966, **9**, 581-591.
- Catania, A. C. and Reynolds, G. S. A quantitative analysis of the behavior maintained by interval schedules of reinforcement. Paper presented at Psychon. Soc., Bryn Mawr, Pa., 1963.
- Conrad, D. G., Sidman, M., and Herrnstein, R. J. The effects of deprivation upon temporally spaced responding. *J. exp. Anal. Behav.*, 1958, **1**, 59-65.
- Farmer, J. and Schoenfeld, W. N. Interreinforcement times for the bar-pressing response of white rats on two DRL schedules. *J. exp. Anal. Behav.*, 1964, **7**, 119-122.
- Ferster, C. B. and Skinner, B. F. *Schedules of Reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Kelleher, R. T., Fry, W., and Cook, L. Interresponse time distribution as a function of differential reinforcement of temporally spaced responses. *J. exp. Anal. Behav.*, 1959, **2**, 91-106.
- Lates, V. G., Weiss, B., Clark, R. L., and Reynolds, M. D. Overt "mediating" behavior during temporally spaced responding. *J. exp. Anal. Behav.*, 1965, **8**, 107-116.
- Malott, R. W. and Cumming, W. W. Schedules of interresponse time reinforcement. *Psychol. Rec.*, 1964, **14**, 211-252.
- Malott, R. W. and Cumming, W. W. Concurrent schedules of IRT reinforcement: Probability of reinforcement and the lower bounds of the reinforced IRT intervals. *J. exp. Anal. Behav.*, 1966, **9**, 317-325.
- McGILL, W. J. Stochastic latency mechanisms. In R. D. Luce, R. R. Bush, and E. Galanter (Eds.), *Handbook of mathematical psychology*. Vol. 1, New York: Wiley, 1963. Pp. 309-360.
- Millenson, J. R. Probability of response and probability of reinforcement in a response-defined analogue of an interval schedule. *J. exp. Anal. Behav.*, 1966, **9**, 87-94.
- Morse, W. H. Intermittent reinforcement. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 52-108.
- Nevin, J. A. and Berryman, R. A note on chaining and temporal discrimination. *J. exp. Anal. Behav.*, 1963, **6**, 109-113.
- Norman, M. F. An approach to free-responding in schedules that prescribe reinforcement probability as a function of interresponse times. *J. math. Psychol.*, 1966, **3**, 235-268.
- Reynolds, G. S. Temporally spaced responding by pigeons: development and effects of deprivation and extinction. *J. exp. Anal. Behav.*, 1964, **7**, 415-421.
- Reynolds, G. S. Discrimination and emission of temporal intervals by pigeons. *J. exp. Anal. Behav.*, 1966, **9**, 65-68.
- Revusky, S. H. Effects of hunger and VI value on VI pacing. *J. exp. Anal. Behav.*, 1963, **6**, 163-169.
- Sidman, M. Time discrimination and behavioral interaction in a free-operant situation. *J. comp. physiol. Psychol.*, 1956, **49**, 469-473.
- Skinner, B. F. *The behavior of organisms*. New York: Appleton-Century-Crofts, 1938.
- Staddon, J. E. R. Some properties of spaced responding in pigeons. *J. exp. Anal. Behav.*, 1965, **8**, 19-27.

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